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Art. XIV.—*The Basalts of the Geelong District.*

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Introduction.

By reason of their association with fossiliferous sedimentary rocks, the ages of the basalts of the Geelong district can be determined with more accuracy than those of similar rocks elsewhere.

The area investigated extends from Footscray westerly to Meredith, then southerly to Airey's Inlet, and is bounded on the east by the sea. The Geological Map of Victoria, published by the Mines Department in 1902, shows the extent of the flows and the positions of the vents.

About 300 rock sections were made at the Geology Department of the University of Melbourne, and the author is indebted to Professor Skeats and his staff for the use of the apparatus. Dr. A. B. Edwards suggested the investigation, and has given much assistance with the petrology.

Cainozoic Succession.

Recent alluvium, beach sand, &c.

Holocene river gravel, dune sand, shell beds.

Pleistocene freshwater limestone.

Newer volcanic series (main flows).

(?) *Upper Pliocene* basalt of Durham Lead.

Upper Pliocene (Werrikooian) calcareous sands.

Lower Pliocene (Kalimnan) sands and ferruginous sands.

Lower Miocene limestones and clays.

Lower Miocene Older Basalt of Maude.

Older volcanic series (main flows).

Oligocene carbonaceous marls of Anglesea, &c.

Oliogocene tuffs of Anglesea.

Age Relations of the Basalts.

Older Volcanic Series.

1. *Anglesea.*

On the beach about $\frac{1}{2}$ mile south of Anglesea is a bed of yellow decomposed tuff known as the Soapy Rock. It is overlain by or interbedded with, carbonaceous marls regarded as Lower Oligocene (Chapman and Crespin, 1935).

2. *Airey's Inlet, Curlewis and Bellarine Hills.*

Older Basalt and tuff underlie Lower Miocene limestone at Airey's Inlet (Chap. & Cresp., 1935) and Curlewis (Singleton, 1935). Two outcrops of limestone near Bellarine (Quarter Sheet 23 S.E.) are probably Lower Miocene, and they overlie Older Basalt.

3. *Waurn Ponds and Mt. Moriac West.*

Small rounded pebbles of decomposed basalt, presumably Older Basalt, have been discovered embedded in the Lower Miocene limestone at Waurn Ponds Old Quarry, Waurn Ponds north quarry in allotment 6, Barrabool, and Cochrane's, allotment 5, Barrabool. The source of this basalt is not clear. The pebbles are obviously resting on the Miocene shoreline, and were derived from a land mass of Older Basalt not far distant, as some of the pebbles attain 4 inches diameter.

West of Mount Moriac, in Prowse's, allotment 17, Modewarre, is a marl pit in Lower Miocene limestone, at the base of which is a layer of basalt pebbles, presumably related to the Older Basalts mentioned above.

4. *Maude.*

At this locality, a flow of Older Basalt is intercalated with beds of Lower Miocene limestone (Singleton, 1935).

Newer Volcanic Series.

The earlier Newer Volcanic lavas filled the river valleys of those times forming "confined lava fields" (Keble, 1918), while the later flows formed the "extended lava fields" of the Western District. The absence of sediments between the flows points to the shortness of the interval between their extrusion.

Generally the lavas rest upon sands or ferruginous sands of Lower Pliocene (Kalimnan) age. Fossils of this age are known from five localities, viz., Shelford (Dennant and Mulder, 1897), Moorabool Viaduct, west bank, (Pritchard, 1897), Lake Connewarre (Coulson, 1935), Cowie's Creek (Stach, 1934) and in allotment 18, Gheringhap, the fossils from the latter being regarded by Mr. R. A. Keble as Kalimnan (personal communication). Recently it has been suggested (Jutson and Coulson, 1937) that the upper unfossiliferous portions of these sandy beds may range up into the Pleistocene. At the Moorabool Viaduct, east bank, there is a limited deposit of calcareous sands containing Upper Pliocene (Werrikooian) fossils (Mulder, 1902) resting on the Kalimnan beds.

1. *Durham Lead (Leigh River).*

Three flows of basalt occur in this lead (Etheridge and Murray, 1874), the lower being separated by 15 feet of sand, and the upper by 7 feet of clay. The valley was eroded through Lower Pliocene sands and Ordovician bedrock. The lowest flow is probably Upper Pliocene. It differs considerably from the others, which are akin to the surface Newer Basalts around Anakie, which are shown later to be Pleistocene in age.

2. *Shelford Lower Flow.*

This may be a southern extension of the Durham Lead system, and has been described by Dennant and Mulder (1898). Although these authors state (p. 88) that the flow is overlain in places by Lower Pliocene sands, the author found that landslips were responsible for this phenomenon, and concludes that the basalt is one of the early Newer Basalts, which it petrologically resembles. The basalt fills a valley eroded in Lower Pliocene sands, and is overlain by the later flows of Newer Basalt.

3. *Batesford Lower Flow.*

Extending from a few miles north-west of the Dog Rocks to beyond Fyansford is a basalt-filled valley of the former Moorabool. It forms the much-discussed lower-level flow along the west side of the present Moorabool River. Its relatively low position is to be attributed to the fact that it flowed over a severely eroded surface, and not to faulting along the course of the Moorabool as previously suggested (Fenner, 1918). The erosion took place in the superimposed valley of the ancestral Moorabool, which developed great scouring power after passing through the granite gorge of the Dog Rocks, and removed the Pliocene sands from the western bank. Bores by the Australian Cement Company at Batesford prove that no north-south fault exists, since the Lower Pliocene beds were found to occur at the same level on both sides of the river.

4. *She Oaks (Moranghurk).*

This confined early flow is described on Quarter Sheet 19 S.W. in Note 2. It is about 2 miles long, and is sectioned in several places by the Moorabool River, exposing a sub-basaltic gravel bed regarded by the Survey as Upper Pliocene in age, but probably Pleistocene. The lower flow is covered by later lava of very similar composition, but with a more holocrystalline texture due to slower cooling.

5. *Anakie Flows.*

These are stratigraphically the most important of the Newer Basalts. For the most part they overlie Lower Pliocene sands, but on the east bank of the Moorabool Viaduct the basalt overlies Upper Pliocene (Werrikooian) calcareous sands (Mulder, 1902), which in turn overlie Lower Pliocene beds. This isolated Werrikooian bed was probably formed in an estuary on the surface of the rising Kalimnan sediments.

Freshwater limestone of Pleistocene age (Pritchard, 1895) overlies the Anakie flows at Lara (Quarter Sheet 24 N.E.) and at the Eastern Beach and Limeburner's Point, Geelong (Quarter Sheet 24 S.E.).

6. *Mt. Duneed Flows.*

These flows overlie Lower Pliocene sands, and the scoria contains fragments of Lower Miocene limestone and of ferruginous sand, probably Lower Pliocene (Coulson, 1935). An error appears in a note on Quarter Sheet 28 N.E. near Mt. Duneed, which states that the supra-basaltic deposits are marine. These deposits are clearly fluviatile.

Along the coast from Bream Creek to Barwon Heads the basalt is overlain by dune sandstones, the lower parts of which are probably as old as Pleistocene, while the upper parts are Recent.

7. *Other Flows.*

The flows from other vents, such as Bald Hill (Balliang), Spring Hill, Mt. Mary, Green Hill (Elaine), Mt. Mercer, Mt. Lawaluk, Mt. Hesse, Mt. Gellibrand, Mt. Pollock, Wurdi Buloc, Mt. Moriac, &c., all overlie Lower Pliocene sands, and are not covered by other formations except Recent alluvium in the river valleys.

Petrographic Types.

Older Volcanic Series.

1. *Iddingsite Titanaugite Labradorite Basalt.*

This type outcrops in the shore platform at Portarlington east of the pier, and is associated with purple tuffs. The texture is somewhat coarse, and the rock consists of large phenocrysts of olivine partially altered to iddingsite, large purple titanaugites ophitic with laths of labradorite and grains of iron ore. Glass is absent. This flow is lowest in the Bellarine Hills suite, and is presumably the oldest.

2. *Olivine Labradorite Basalt.*

This is the commonest type among the Older Volcanics. It occurs in the volcanic neck at Curlewis (Coulson, 1932), is the main flow in the Bellarine Hills (sampled in allotment 24, Bellarine) and occurs at Maude (allotment 17, Darriwil). The rock is black, non-vesicular, and consists of medium-sized phenocrysts of olivine thinly rimmed with golden iddingsite, divergent laths of labradorite and intersertal zoned felspar, intergranular short prisms of pale violet augite, large grains of iron ore, and some green serpentinic glass.

A chilled variety occurs among tuff in a quarry in allotment 8, Bellarine. The lava blocks consist of basalt of hemi-crystalline texture, showing small phenocrysts of olivine, short single laths of (?)labradorite, and much intersertal brown glass full of minute grains of iron ore. This quarry is close to one of the old vents. Keble (1918) regarded the Bellarine lavas as infilling an ancient valley trending from north to south, but to account for the tuff, and the disturbed Jurassic bedrock (Daintree, 1862) it is necessary to postulate local centres of eruption.

A peculiar type, limited to Harding's Hill, allotment 15, Bellarine, is a dark-grey basalt consisting of microphenocrysts of olivine completely replaced by skeletal iron ores, which in many cases retain the euhedral outline of the original olivine, in an intergranular base of plagioclase laths. There has been an introduction of calcite, and a little epidote has formed. This flow is the uppermost of the Bellarine suite, and presumably the youngest.

3. *Olivine Labradorite Basalt.*

At Airey's Inlet, the Older Basalt underlies Lower Miocene limestone, but east of Split Point it is replaced by tuffs, which disappear below sea level about 1 mile from the point. The basalt is medium grained, black, non-vesicular, and consists of small phenocrysts of olivine partly serpentinized, long laths of labradorite and large square grains of magnetite set in an intergranular groundmass of felspar laths and pyroxene prisms.

4. *Olivine Labradorite Titanaugite Basalt.*

This titaniferous basalt is exposed along the east bank of the Moorabool River between Maude and Russell's Bridge, from allotment 12A to 5C, Darriwil. The olivine forms abundant phenocrysts up to 5 mm. diameter, generally partially serpentinized or altered to chlorophaeite. These are set in a relatively coarse groundmass of sub-ophitic intergrowths of crystals of titanaugite and labradorite laths, interspersed with patches of green felspathic glass, rods of iron ore, and needles of apatite.

Newer Volcanic Series.

1. *Olivine Labradorite Basalt (Footscray Type).*

Specimens for microscopic examination were taken at close intervals on the Newer Basalt plains, but except at the vents none was found which could not be included in the "Footscray" type (Edwards, 1937). Rather wide variations of texture are allowed in this group to include the effects produced by different rates of cooling. The holocrystalline rock from the central portions of flows, obtained rather rarely in river sections or deep quarries, is a grey vesicular basalt consisting of large allotriomorphic and corroded olivines, heavily margined with reddish-brown iddingsite, laths of labradorite (Ab_{50}), much intersertal zoned felspar with undulose extinction, some corroded crystals of (?)anorthoclase, ophitic colourless or pale violet augite, or occasionally titanaugite, long rods of ilmenite and some grains of magnetite.

Much more common is the variety which contains glass. The introduction of glass usually means a reduction in the amount of iddingsite and intersertal zoned felspar, a change to greenish augite, and the inclusion of skeletal iron ores in the brown glass.

On the upper and lower margins of flows, more than half the rock section may consist of black glass full of minute grains of iron ores, with phenocrysts of idiomorphic olivine, sharply defined laths of labradorite or andesine, and sub-ophitic colourless augite.

2. *Olivine Basalt* (*Ballan Type*).

At the actual vents throughout the area, and in very short flows about them, a dense grey basalt occurs, with micro-phenocrysts of olivine heavily rimmed with red-brown iddingsite, fine groundmass of very short laths of andesine and indeterminate felspar, minute granular colourless, sometimes pale violet, augites, and extremely small grains of iron ore. This description conforms with that of the Ballan type (Edwards, 1937). It occurs at the Anakies, Bald Hill and Spring Hill (Balliang), Green Hill (Elaine), Green Hill (Cargerie), Mt. Duneed, Mt. Moriac, Pettavel, Waurn Ponds, Wurdi Boluc, Mt. Pollock, Staughton's Bridge (Werribee River), Mt. Cotterill, Mt. Kororoit, Greek Hill, McDiarmid's Hill, &c.

At the Anakies and Mt. Kororoit, scoriaceous and tachylitic rocks are associated with the Ballan type. They contain large phenocrysts of olivine lightly iddingsitized, occasional phenocrysts of anorthoclase and indeterminate felspar with undulose extinction, and extremely minute grains of black glass or iron ore.

The Wurdi Boluc specimen from a 550-foot hill south of Lake Wurdi Boluc, is unusual, consisting of small rounded crystals of olivine partly iddingsitized, and abundant small grains of iron ore set in an extremely fine groundmass of felspathic laths and pyroxene crystals.

Mt. Pollock, described by Hall (1910) as a lava-capped outlier, is composed of Ballan type basalt, quite different from the surrounding lava plain, and the rock at its summit contains inclusions of Tertiary sandstone. It is therefore a true volcano.

The Durham Lead basalt is of coarse felspathic rock with abundant laths of oligoclase and much intersertal plagioclase with undulose extinction, small clear olivines without iddingsite, some titaniferous augite, thin rods of iron ore, and some yellow cloudy glass.

Summary.

Pleistocene	Olivine Basalt (Ballan type). Olivine Labradorite Basalt (Footscray type).
Upper Pliocene	Olivine Oligoclase Titanaugite Basalt (Durham Lead).
Lower Miocene	Olivine Labradorite Basalt (Maude).
Lower Miocene or Oligocene	Olivine Labradorite Titanaugite Basalt. Olivine Labradorite Basalt. Iddingsite Labradorite Titanaugite Basalt.
Oligocene	Tuffs (Anglesea).

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